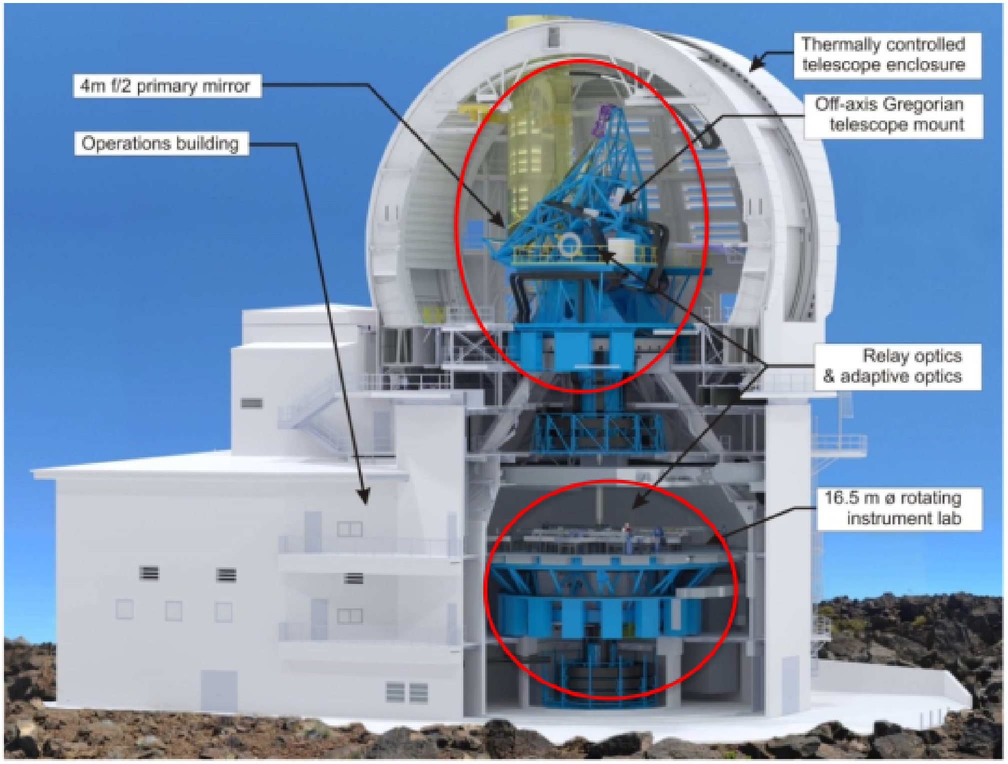
Solar Orbiter-DKIST Coordinated Observations

V. Andretta (INAF/OAC)
L. Harra (UCL/MSSL)
V. Martinez-Pillet (NSO)

The Daniel K. Inouye Solar Telescope (DKIST)

- Four-meter aperture, f/2
- Alt/azimuth mount
- All reflecting optics
- Off-axis design (no spider, no central obscuration)
- Heat stop at prime focus: hard limit of 5' FOV
- Low-scattered light
    - Coronagraph
    - Lyot stop & limb occulter
    - In situ clean & wash of M1
- Integrated adaptive optics (on-disk)
- High-precision polarimetry
- Thermally controlled environment.
- Service Mode: PI not present.
- Data available on-line: Boulder DC



NSO

The Daniel K. Inouye Solar Telescope (DKIST)

The Daniel K. Inouye Solar Telescope
(DKIST, formerly the Advanced Technology Solar Telescope, ATST):

- 4m aperture -► **25 km, SNR≈10^4**
- Designed for simultaneous multiline diagnostics
- Designed for accurate and sensitive polarimetry
- Designed for coronal off-limb observations

- Low-scattered light
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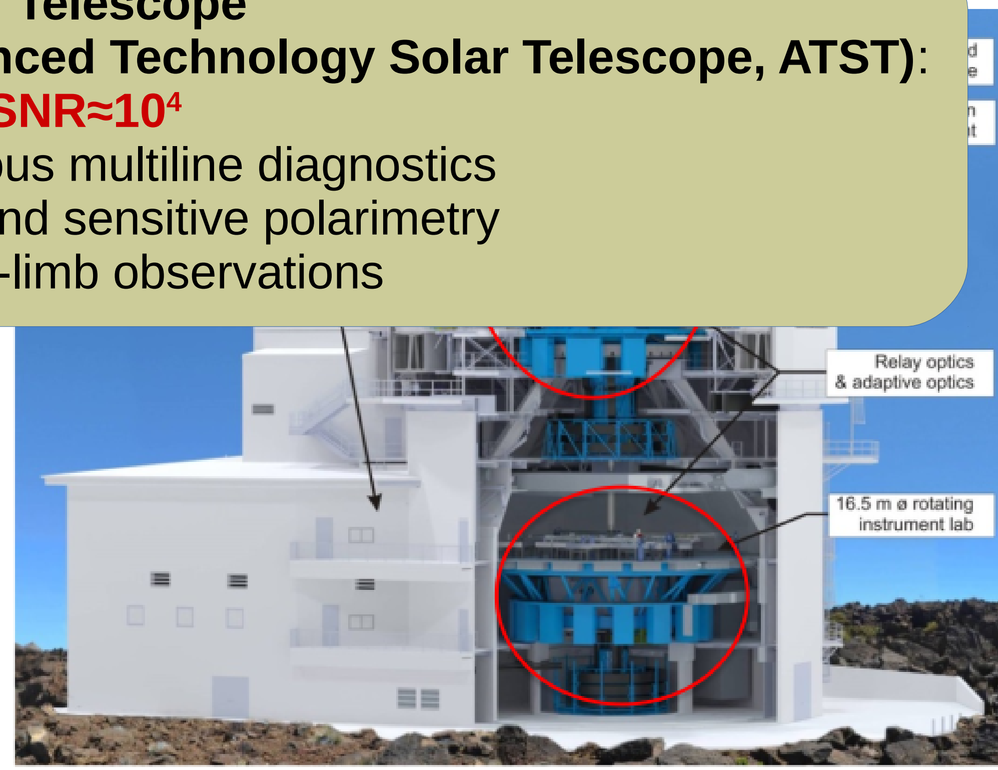

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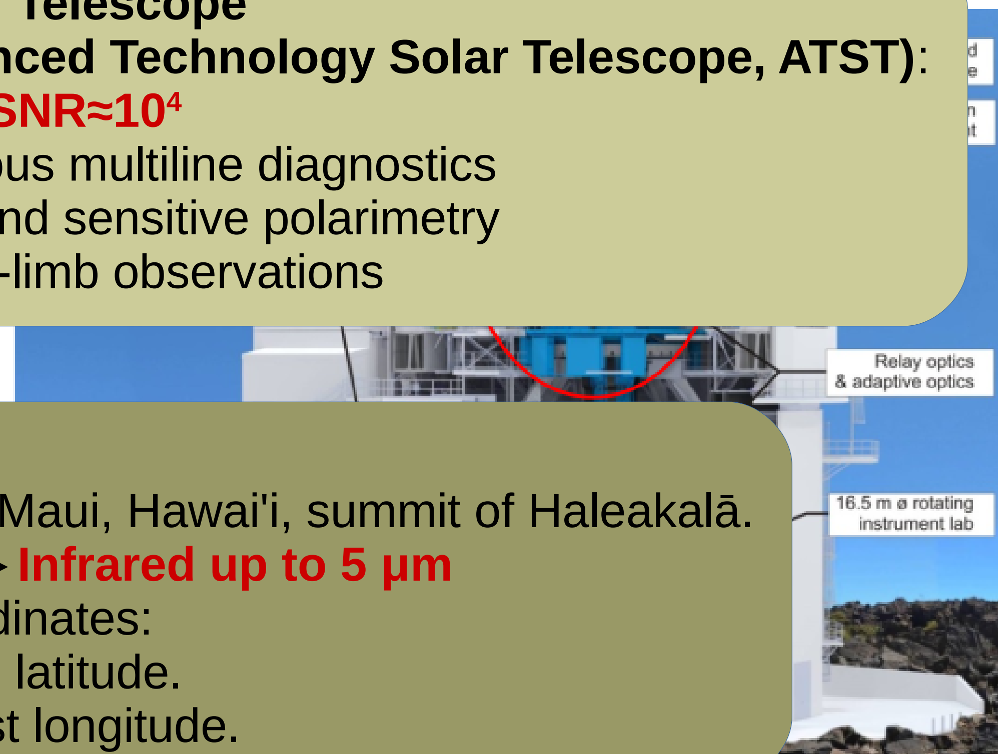
- Low-scattered light
  - Coronagraph
  - Ly
  - In
- Integra
- High-p
- Therm
- Service
- Data av



Site Information

- Location: Island of Maui, Hawai'i, summit of Haleakalā.
- Altitude: 3067 m -► **Infrared up to 5 µm**
- Geographical coordinates:
  - 20° 42' 24" North latitude.
  - 156° 15' 23" West longitude.

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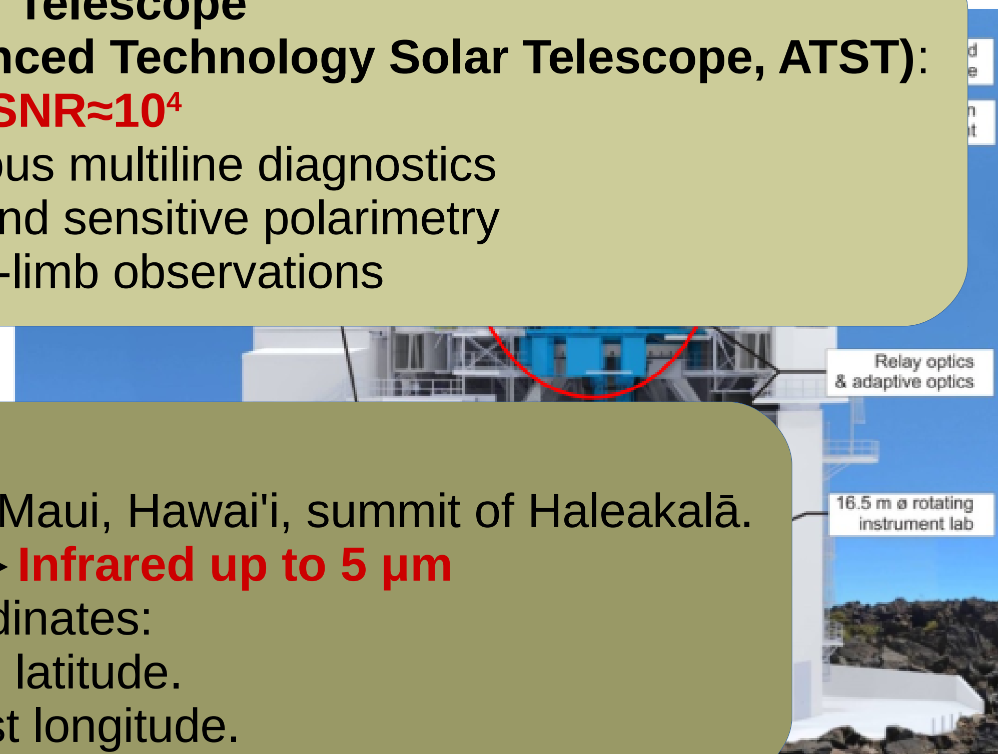

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- Geographical coordinates:
    - 20° 42' 24" North latitude.
    - 156° 15' 23" West longitude.

First light:
End of 2019

DKIST First-light Instruments

National Science Foundation

DKIST First Light Instrument Capabilities

	Instrument type	Spectral range	Spectral resolution	Spatial sampling	Maximum Instantaneous Field of View	Maximum Sampled Field of View	Peak Cadence	Analogous Instruments
Visible Broadband Imager ***VBI (Blue)***	High Cadence, High Resolution Imager	390–550nm (sequential filter sequencing)	N/A	0.011″	45″ x 45″	2′ x 2′ (sequential field sampling)	3.2 sec (reconstructed) 0.03 sec (raw images)	ROSA, Hinode/BFI *High cadence, high spatial resolution*
Visible Spectropolarimeter ***ViSP***	Scanning Slit Spectropolarimeter	380-900nm (3 spectral windows at a time)	>180,000	0.0195″ (arm 1) 0.0236″ (arm 2) 0.0295″ (arm 3) [sampling along slit]	*5 slits* *Width* x *Length* 0.028″ or 0.041″ or 50″ (arm 1) 0.053″ or x 60″ (arm 2) 0.106″ or 75″ (arm 3) 0.214″	Slit length x 2′	0.5-10 sec per slit position (polarimetry) 0.02-0.2 sec per slit position (intensity-only)	SPINOR, Hinode/SP, IRIS, GRIS *Scanning spectrograph, high spectral fidelity*
Visible Tunable Filter ***VTF***	Fabry Perot Imaging Spectropolarimeter	520-870nm (sequential scans through multiple spectral lines)	FWHM 6-8 pm	0.014″	60″ x 60″	60″ x 60″	Typical scan times per spectral line: 0.5-2 s (intensity only); 2-10 s (polarimetry)	IBIS, CRISP, GFPI *Imaging spectropolarimeter*
Visible Broadband Imager ***VBI (Red)***	High Cadence, High Resolution Imager	600–860nm (sequential filter sequencing)	N/A	0.017″	69″ x 69″	2′ x 2′ (sequential field sampling)	3.2 sec (reconstructed) 0.03 sec (raw images)	ROSA, Hinode/BFI *High cadence, high spatial resolution*
Diffraction Limited Near Infrared Spectropolarimeter ***DL-NIRSP***	Integral Field Unit Spectropolarimeter	500–900nm 900–1350nm 1350-1800nm (1 filter band per channel)	125,000	0.03″ (high res) 0.077″ (mid res) 0.464″ (wide field)	2.4″ x 1.8″ (high res) 6.16″ x 4.62″ (mid res.) 27.84″ x 18.56″ (wide)	2′ x 2′	Depends on resolution and and total field of view. E.g. 6s for one tile, on-disk, high resolution, full polarimetry	SPIES *True Imaging Spectropolarimeter: simultaneous 2D FOV and spectral information using fiber-fed IFU*
Cryogenic Near Infrared Spectropolarimeter ***Cryo- NIRSP***	Scanning Slit Spectropolarimeter	1000-5000nm (1 filter band at a time. About 70 s to switch filters)	100,000 on-disk 30,000 off-limb	0.12″ [along slit] (no Adaptive Optics)	*2 slits* 0.15″ x 120″ slit 0.5″ x 240″ slit	4′ x 3′ (near limb) 5′ round (off-limb)	Heavily depends on signal to noise. Maximum frame rate is 10 frames per second e.g. 1s per slit position near-limb/ chromosphere	CYRA (BBSO) *Cryogenic, scanning spectrograph, novel diagnostics*
Cryo-NIRSP ***Context Imager***	Imager	1000-5000nm (1 filter band at a time, with fast switching time to support sequential observations during a single-band spectrograph scan.)	N/A	0.052″ (no Adaptive Optics)	100″ x 100″	4′ x 3′ (near limb) 5′ round (off-limb)	Heavily depends on signal to noise. Maximum frame rate is 10 frames per second e.g. 1s per slit position near-limb/ chromosphere	CYRA (BBSO) *Cryogenic, scanning spectrograph, novel diagnostics*

This table is meant to give an idea of the capabilities of the DKIST first light instrument suite. It cannot capture the large trade space that is provided by the flexibility of the instruments. For more information, visit http://dkist.nso.edu/CSP/instruments

https://www.nso.edu/telescopes/dkist/

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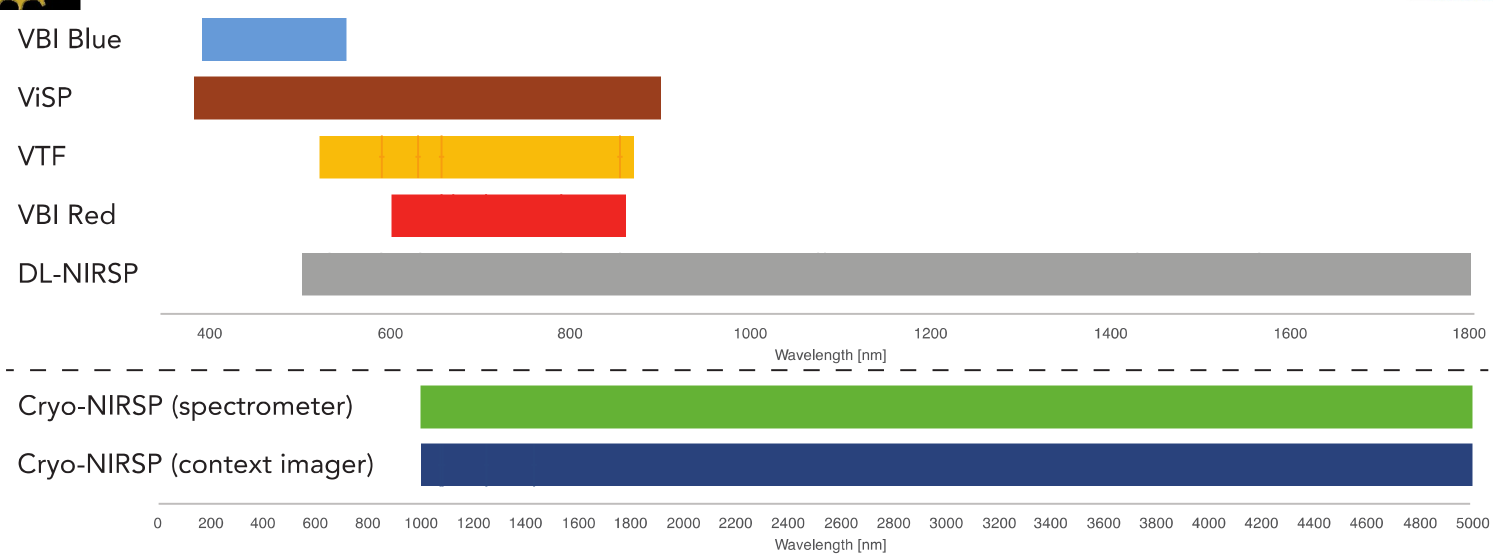
www.nso.edu

DKIST First-light Instruments

National Science Foundation

DKIST First Light Instrument Filters



VBI Blue

Ca II K	393.327nm
G-band	430.52nm
Continuum	450.287nm
H-beta	486.1nm

ViSP

Access to entire spectral range between 380-900 nm

VTF

Na D	589.6nm
Fe I	630.25nm
H-alpha	656.3nm
Ca II	854.2nm

VBI Red

H-alpha	656.282nm
Continuum	668.423nm
Ti O	705.839nm
Fe XI	789.186nm

DL-NIRSP

Fe XIV	530.3 nm
He I	587.6 nm
Fe I	630.2 nm
Fe XI	789nm
Ca II	854.2nm
Fe XIII	1074.7nm
He I	1083nm
Si X	1430nm
Fe I	1565nm

Cryo-NIRSP

Fe XIII	1074.7nm
Fe XIII	1079.7nm
He I	1083 nm
Si X	1430nm
Si IX	3935 nm
CO	4651nm

Cryo Context

Fe XIII	1074.7nm
He I	1083nm
J Band	1250nm
Si IX	1430nm

This table is meant to give an idea of the capabilities of the DKIST first light instrument suite. It cannot capture the large trade space that is provided by the flexibility of the instruments. For more information, visit http://dkist.nso.edu/CSP/instruments

Visible light cameras for instruments are provided by a UK consortium.

https://www.nso.edu/telescopes/dkist/

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DKIST Coronal Capabilities

DKIST: Transformative Coronal Features

Excellent Haleakala Skies!

*~**1000** hours per year with sky brightness <25 x 10^{-6} at R = 1.1 and at 1000 nm.*

4 meter aperture → 25 km; SNR!

Access to the infrared:

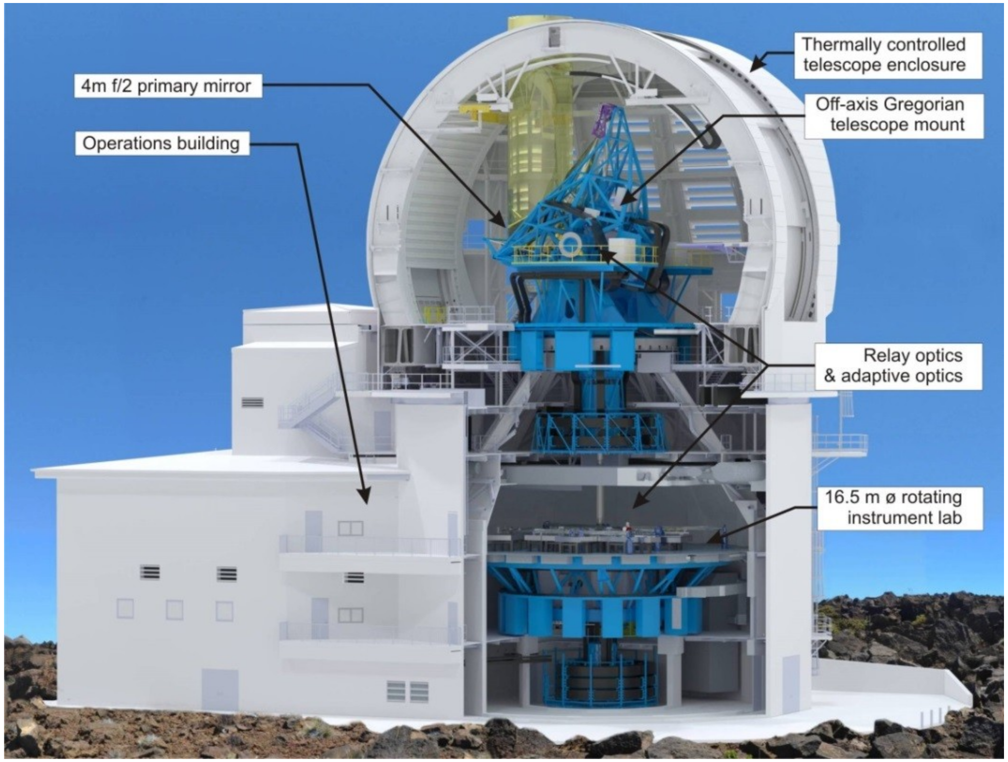
All-reflective design (transmission out to 28 μm)
First light instruments to 5 μm

Minimizes scattered light by:

Off-axis design (no beam obsuration)
High-grade M1 polish (~1nm microroughness)
In-situ cleaning procedures (CO_2 + washing)
Takes advantage of reduced scatter in IR.

Occulters and stops:

Inverse occulter at prime focus (large 5' FOV)
Lyot stop at intermediary pupil
Limb occulting with tracking at Gregorian focus



(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities

DKIST: Broad Coronal Science Mission

Key coronal science areas from SPEC-0001 (Science Requirements Documents):
Derived from reports of the Coronal Working Group (2002)

1) Coronal Magnetic Fields
   - *Pre/post CME/flare configurations; field dynamics during eruptions; origin of coronal loops; prominence cavities; etc.*
2) Coronal Plasmoid Search
   - *Mass flux and acceleration mechanisms of plasmoids; field interactions*
3) Coronal Velocity and Density in Active Regions Loops
   - *Loop evolution and structure; nature and mechanisms and energy deposition, heating; loop classification*
4) Coronal Intensity Fluctuation Spectrum
   - *Size and spatial distribution of possible nano-flaring events, relation to CMEs*
5) Coronal Intensity Oscillations
   - *Coronal seismology to obtain coronal physical parameters and understand wave dynamics*

DKIST supports mission with diverse imaging, scanned-slit spectroscopy and spectro-polarimetry, and fiber-optic based integral field spectroscopy and spectropolarimetry.

(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities

DKIST coronal diagnostics during early operations

- Emphasis on bright line observations with greatest magnetic field sensitivity.
- Corresponding peak temperature coverage: 1 to 1.6 MK
- Filter availability can be expanded in the future.

Maximum FOV: 2.8 arcmin -- Coordinated Operations

DL-NIRSP Spectropolarimetry

Fe XI λ7892 ; Log(T) ~ 6.13
Fe XIII λ10747 ; Log(T) ~ 6.22
Fe XIII λ10797 ; Log(T) ~ 6.22
He I λ10830 ; Log(T) ~ 4*
Si X λ14300 ; Log(T) ~ 6.13

VBI Imaging

Fe XI λ7892 ; Log(T) ~ 6.13

VISP Spectropolarimetry

Various lines: 380 to 900 nm
Including FeXIV 5303, FeX 6375,
(green + yellow lines)

Maximum FOV: 5 arcmin

Cryo-NIRSP Spectropolar.

Fe XIII λ10747 ; Log(T) ~ 6.22
Fe XIII λ10797 ; Log(T) ~ 6.22
He I λ10830 ; Log(T) ~ 4*
Si X λ14300 ; Log(T) ~ 6.13
Si IX λ39350 ; Log(T) ~ 6.04

Cryo-NIRSP Context Imager

Fe XIII λ10747 ; Log(T) ~ 6.22
He I λ10830 ; Log(T) ~ 4*
Si IX λ39340 ; Log(T) ~ 6.04

DKIST NSF NSO National Solar Observatory AURA

5

(Slide borrowed from Tom Schad)

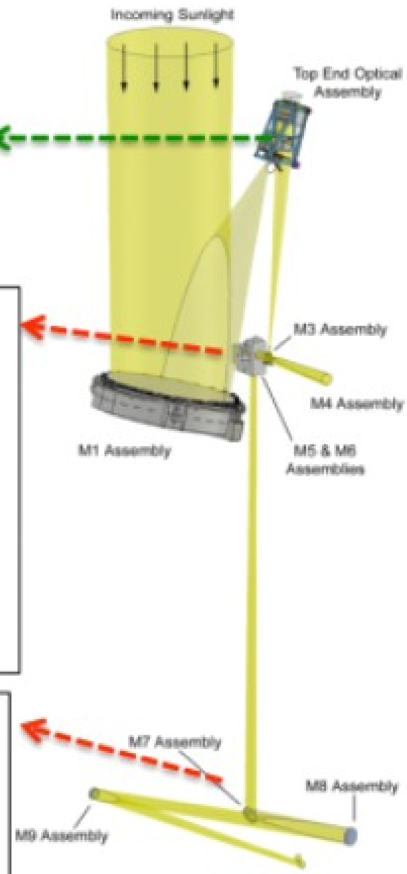
DKIST Coronal Capabilities

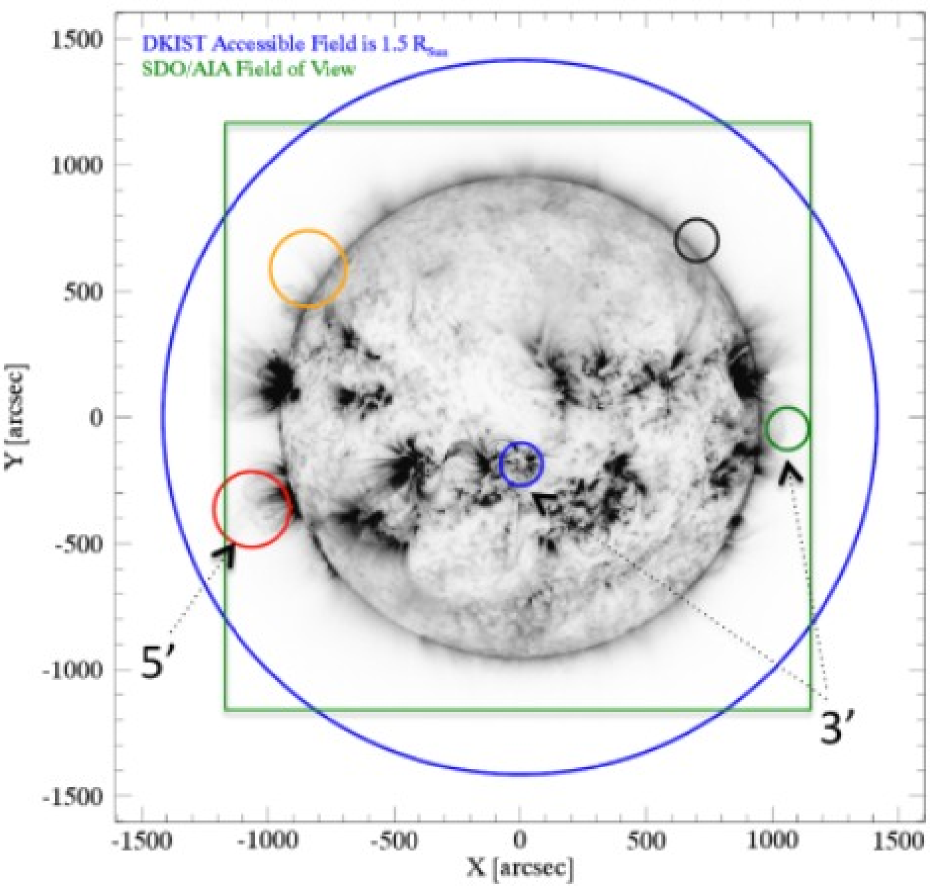
Field of View, Pointing Restrictions (R<1.5 R_{sun}), and Occulters

Prime field stop
"inverse occulter"
5 arcmin diameter

Gregorian focus (GOS): 2.8 and 5 arcmin apertures, limb occulters, and polarization calibration optics

Instruments. Cryo-NIRSP can use 5′, others 2.8′ FOV

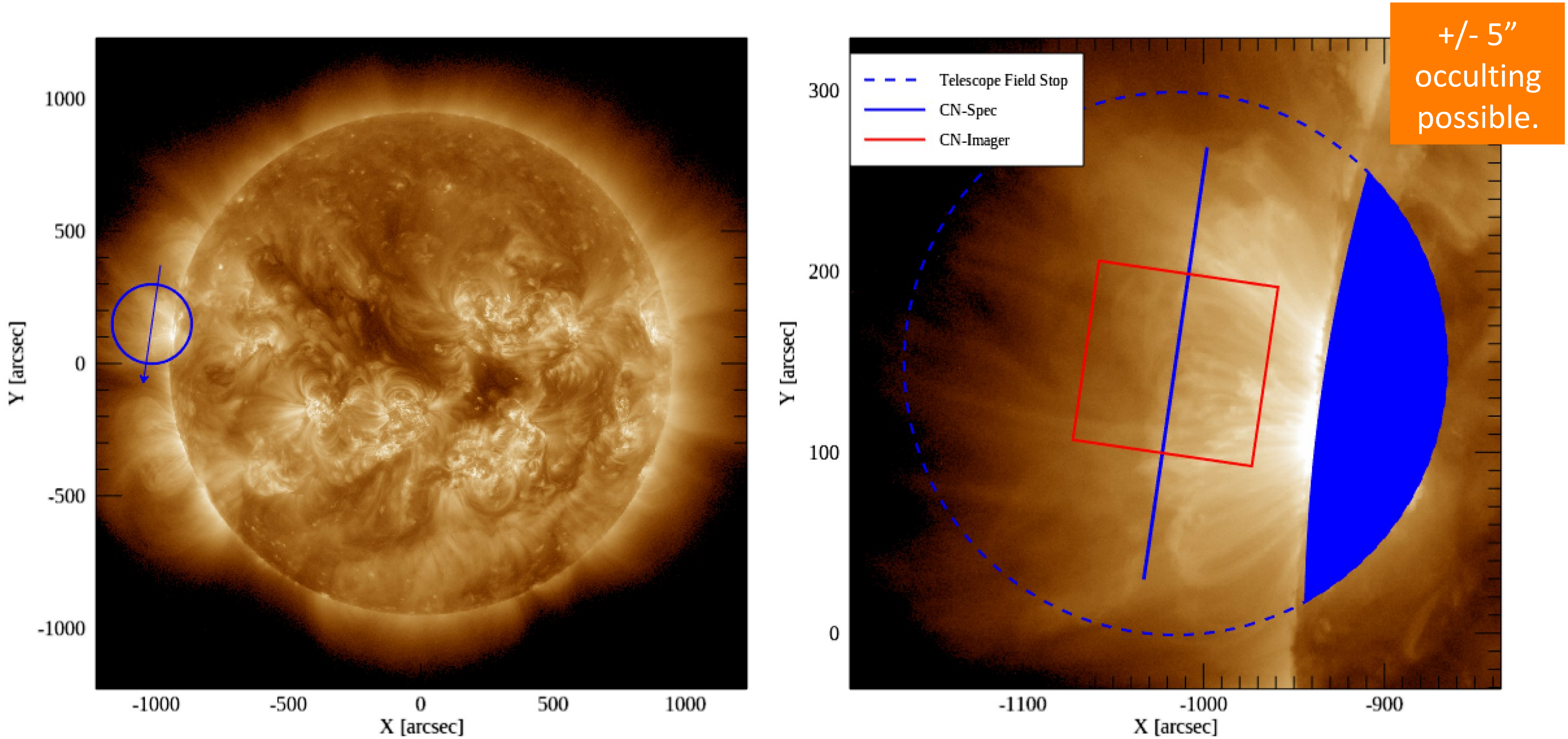




(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities

Cryo-NIRSP Example: 5 arcmin field-of-view with limb occulter (blue)

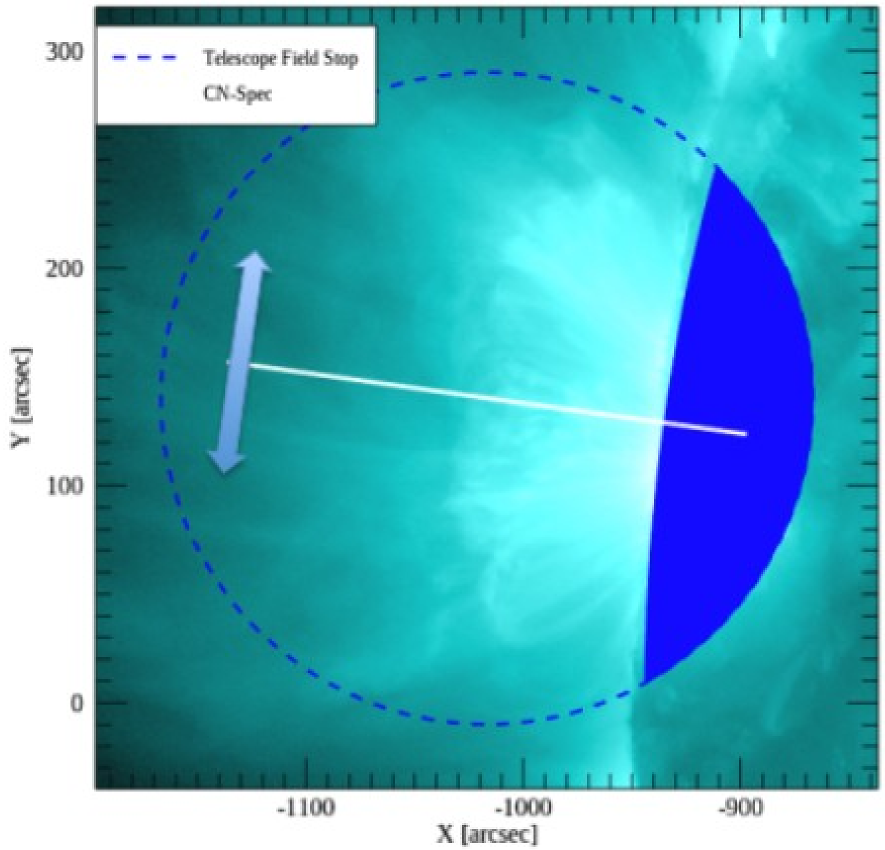


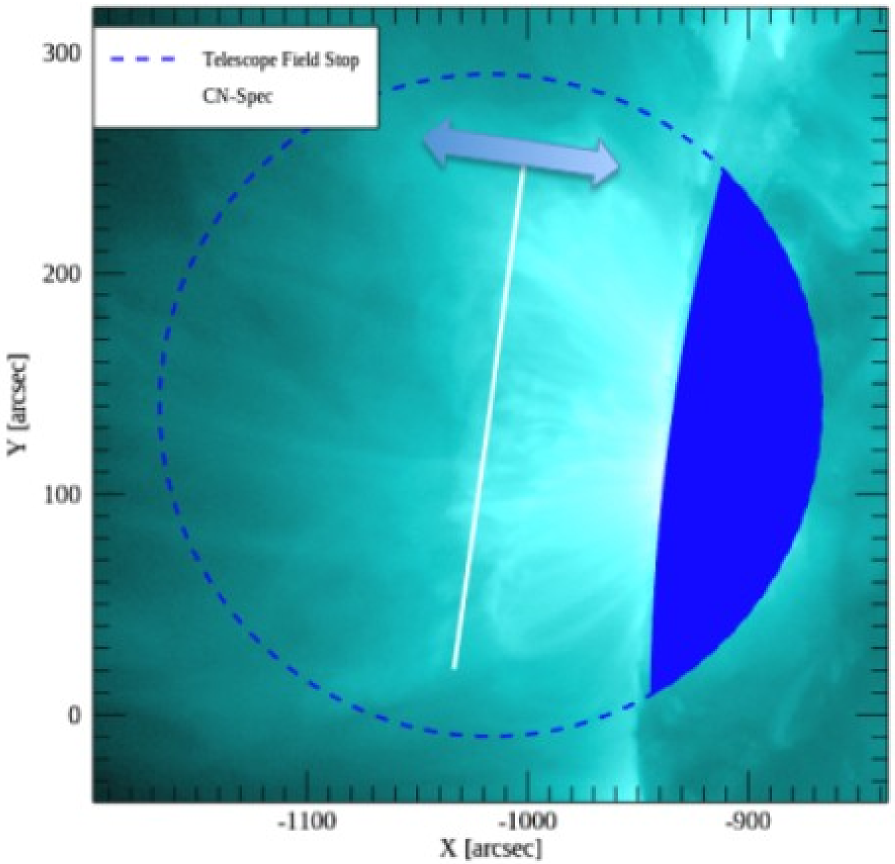
Instruments have smaller instantaneous field of views, but most can scan field.

(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities

Cryo-NIRSP 4’ long coronal slit: Perpendicular/parallel to limb with occulter

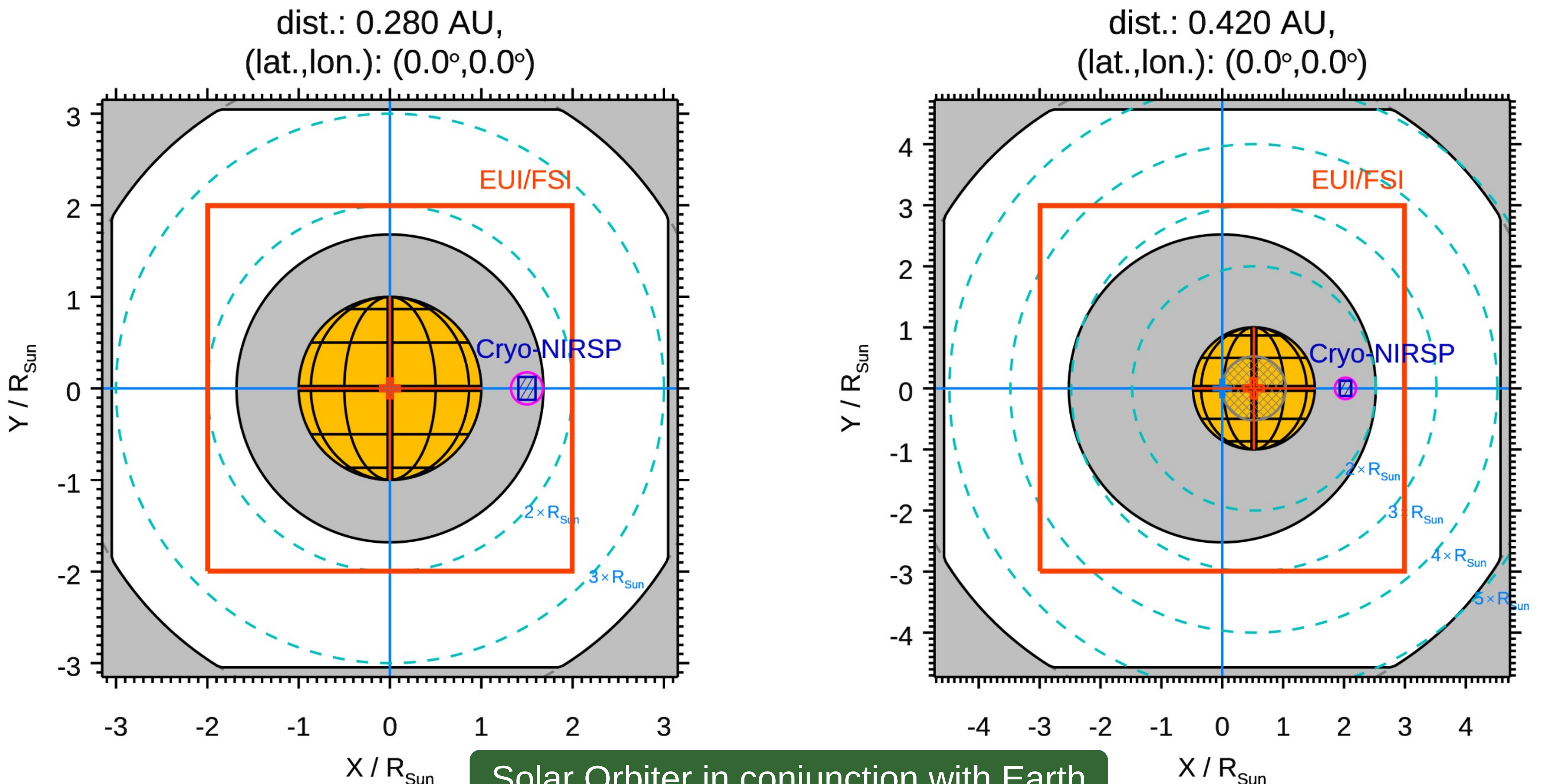




*CN also has 2D scan patterns available

(Slide borrowed from Tom Schad)

DKIST and Metis



Solar Orbiter in conjunction with Earth

DKIST Critical Science Plan (CSP)

- **The DKIST Critical Science Plan (CSP)**

  (being drafted) will define critical science goals for the first two years of DKIST operations. https://www.nso.edu/telescopes/dkist/csp/

- **Science Use Cases (SUCs):**

  The Critical Science Plan will be built up from a set of PI led Science Use Cases (SUCs).

- **These SUCs will be converted into Observing Proposals**

  for consideration by the DKIST Time Allocation Committee (TAC) before first light.

- **Nine workshops have taken place in the past year**

  to facilitate this process at several steps. These are organized by community members and supported by the NSO.

The Solar Orbiter-PSP-DKIST Workshop

- **Workshop #4, title:**

  Joint Science with Solar Orbiter and Parker Solar Probe

  13-15 March 2018, JHU/APL, Laurel (MD, USA)

- **Science leaders:**

  L. Harra (UCL/MSSL)

  V. Andretta (INAF/OAC)

  A. Vourlidas (JHU/APL) – Host institution

- **Local contact at host institution (JHU/APL):**

  A. E. Raouafi, A. Vourlidas

Science Use Cases from the Workshop

Almost 30 Science Use Cases (SUCs) so far

Some (18) worked on in detail during the workshop.

Others updated or even created after the workshop.

Some SUCs elaborated during other workshops could also benefit from SO and/or PSP coordination.

More SUCs involving Solar Orbiter added after/following the workshop.

Work in progress...

A follow-up workshop is needed

to consolidate SUCs with Solar Orbiter and PSP, this time involving more directly the in-situ instrument teams. Likely to be held spring 2019 in the US (at location TBD) – all PIs will be invited.

Current List of Science Use Cases

Use Case Development Platform: Altassian's JIRA
https://nso-atst.atlassian.net/projects/UC/board

1–18 of 18

Columns

T	Key	Summary	Assignee	Reporter	P	Status	Resolution	Created	Updated	Due
	UC-162	DKIST and Solar Orbiter observations for understanding upflowing plasma on the Sun: limb observations for DKIST, quadrature for SO.	Louise Harra	Louise Harra		OPEN	*Unresolved*	03/Apr/18	11/Aug/18	
	UC-161	Stereoscopy of polar magnetic fields	Luis Bellot Rubio	Luis Bellot Rubio		OPEN	*Unresolved*	15/Mar/18	11/Aug/18	
	UC-160	What is the Magnetic Flux in Coronal Holes?	linkerj@predsci.com	linkerj@predsci.com		OPEN	*Unresolved*	15/Mar/18	28/Sep/18	
	UC-159	Stereoscopic Observations of Loops and Magnetic Fields	Harry Warren	Harry Warren		OPEN	*Unresolved*	15/Mar/18	11/Aug/18	
	UC-158	Understanding the Line-of-Sight integration in Coronal observations	Valentin Pillet	Valentin Pillet		OPEN	*Unresolved*	15/Mar/18	11/Aug/18	
	UC-157	Waves and turbulences in the nascent solar wind with Solar Orbiter and Parker Solar Probe	yuan-kuen.ko	yuan-kuen.ko		OPEN	*Unresolved*	14/Mar/18	11/Aug/18	
	UC-156	Plasma Dynamics and Inner Structure of Coronal Plumes	Nour E. Raouafi	Nour E. Raouafi		OPEN	*Unresolved*	14/Mar/18	11/Aug/18	
	UC-155	Coronal prominence cavity systems - with DKIST-Solar Orbiter joint observations	Susanna Parenti	Sarah.Gibson		OPEN	*Unresolved*	14/Mar/18	11/Aug/18	
	UC-154	Searching for flare current sheet instabilities with DKIST and Solar Orbiter	Sarah Matthews	Sarah Matthews		OPEN	*Unresolved*	09/Mar/18	11/Aug/18	
	UC-153	Stereoscopic magnetic field measurements: joint observations with Solar Orbiter / PHI	Andreas Lagg	Andreas Lagg		OPEN	*Unresolved*	06/Mar/18	11/Aug/18	
	UC-152	Helicity mapping for dynamo studies (also in coordination with solar Orbiter high-latitude phase)	Andreas Lagg	Andreas Lagg		OPEN	*Unresolved*	06/Mar/18	10/Oct/18	
	UC-151	Polar magnetic fields from two vantage points: joint observations with Solar Orbiter	Andreas Lagg	Andreas Lagg		OPEN	*Unresolved*	06/Mar/18	11/Aug/18	
	UC-90	Synoptic Coronal Observations in support of PSP and Solar Orbiter	Valentin Pillet	Valentin Pillet		OPEN	*Unresolved*	08/Dec/17	11/Aug/18	
	UC-89	Tracking the evolution of Corona Mass Ejections plasma	Daniele Spadaro	Daniele Spadaro		OPEN	*Unresolved*	04/Dec/17	11/Aug/18	
	UC-88	Properties of the solar wind source regions investigated by DKIST and Solar Orbiter	Daniele Spadaro	Daniele Spadaro		OPEN	*Unresolved*	04/Dec/17	11/Aug/18	
	UC-64	FIP fractionation as tracer of solar wind source regions from joint DKIST and Solar Orbiter observations.	Susanna Parenti	Susanna Parenti		ACTIVE	*Unresolved*	12/Sep/17	11/Aug/18	
	UC-61	DKIST and Solar Orbiter observations for understanding the creation of upflowing plasma on the Sun - on disk observations.	Louise Harra	Louise Harra		OPEN	*Unresolved*	20/Jun/17	11/Aug/18	
	UC-60	Coronal helium abundance from joint DKIST and Solar Orbiter observations	Vincenzo Andretta	Vincenzo Andretta		OPEN	*Unresolved*	16/May/17	11/Aug/18	

1–18 of 18

Some points worthy of note

- **Connection between DKIST CSP and Solar Orbiter SAP.**
  - TBW
- **DKIST CSP time frame: 2020-2021 ➡ Solar Orbiter Cruise Phase.**
  - For Nominal/Extended Phase science (especially polar science), the approach is still valid: relevant SUCs are carried over to the next cycle of DKIST CSP development.
- **Planning with variable seeing/sky conditions at DKIST site**
  - Weather forecasts at Maui are known reasonably accurately 2 days in advance. It may be sufficient for switching to alternate observing plans.
- **Data policy**
  - The DKIST data and access policy is being worked out in the framework of the Astronomy and Astrophysics Advisory Committee Principles for Access

    https://www.nsf.gov/mps/ast/aaac/aaac_2014_principles_for_access-v2.pdf

    Following these recommendations, DKIST is open access, and all the data from the facility will be openly available through the DKIST website in a timely manner. However, a period of limited access to the data might exists in some cases that are under discussion at the DKIST Science Policy Advisory Committee. NSO will publicize the final DKIST data access policy during the first half of 2019.

Additional material

The DKIST Critical Science Plan

DKIST Critical Science Plan (CSP)

Introduction to the DKIST Critical Science Plan; and life cycle of a Science Use Case (SUC)

- DKIST Critical Science Plan – context, resource locations
- Workshop focus – Science Use Case (SUC) development
- The future – transition to Observing Proposals

(The following slides borrowed from Mark Rast)

DKIST Critical Science Plan (CSP)

DKIST Critical Science Plan (CSP):

Aim: to be ready, *as a community*, by science first light to execute a set of observations that take advantage of the DKIST capabilities to address critical compelling science in the first two years of operations (2020, 2021)

As a community we must:

- understand forthcoming capabilities
- define science goals
- compile Science Use Cases
- coordinate to form a complementary set of PI lead teams
- convert Science Use Cases into PI led Observing Proposals

This will enable:

- Service Mode observations
- Scientific analysis
- PI led publication of first-light results

DKIST Critical Science Plan (CSP)

DKIST Critical Science Plan (CSP):

Aim: to be ready, *as a community*, by science first light to execute a set of observations that take advantage of the DKIST capabilities to address critical compelling science in the first two years of operations (2020, 2021)

Solar Orbiter Cruise Phase

As a community we must:

- understand forthcoming capabilities
- define science goals
- compile Science Use Cases
- coordinate to form a complementary set of PI lead teams
- convert Science Use Cases into PI led Observing Proposals

This will enable:

(Slide borrowed from Mark Rast)

- Service Mode observations
- Scientific analysis
- PI led publication of first-light results

Science Use Case → Observing Proposal → TAC Review → Observations

DKIST Critical Science Plan (CSP)

Untitled — Edited

dkist.nso.edu/CSP

Web of Scien...lection Home Homepage - A...ata Analysis Noteshelf AirTransfer DKIST Critical... Plan | DKIST Album: images SpectroWeb

NSO DKIST

DANIEL K. INOUYE SOLAR TELESCOPE NSO NISP Education

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- Critical Science Plan
  - Research Areas
  - Science Use Case Development (JIRA)
  - Instrument Suite
  - Science Working Group
- Engineering
- Meetings
- Library
- Log In

DKIST Critical Science Plan

The DKIST Critical Science Plan (CSP) is being formulated (these pages). It will define critical science goals for the first or two years of DKIST operations, and in the process help refine data handling procedures and science operations. The aim is to be ready by start of operations to execute a set of observations that take advantage of the DKIST capabilities to address critical compelling science. The Critical Science Plan will be built up from a set of PI led Science Use Cases (team or individual efforts). These will be converted into Observing Proposals for consideration by the DKIST Time Allocation Committee (TAC) before first light.

Most CSP observations will be conducted in *Service Mode*, though *Access Mode* will also available to support specific needs. Along with standalone DKIST projects, coordinated observations with other observing facilities or platforms are encouraged and will be supported to meet the science goals.

As scientific goals are expected to evolve between now and DKIST first light, we anticipate that the development of the CSP will be an iterative process subjected to adjustment and revision. The development steps currently envisioned:

1. Submission of Science Use Cases (**Science Use Case Preparation**) by a broad range of community members, to include:
   a. a statement of the scientific goals
   b. a definition of the required instrument suite to be employed
   c. an assessment of the multi-instrument configuation compatibility
   d. a description of the basic data needs (image or spectra, wavelengths, cadences, and photometric, spectroscopic and polarimetric precisions)
   e. a summary of the observing strategy and any joint facility coordination needs
2. Coordination of Science Use Cases (**Science Use Case Preparation**), to include:
   a. reformulation of DKIST Critical Science Plan based on Science Use Cases submissions
   b. self organization of Science Use Cae teams to consolidate effort
   c. identification of Science Use Case team leads (to serve as Observing Proposal PIs)

This coordination phase aims to minimize overlap of individual Science Use Cases. It is not required, and overlapping proposals can be submitted to the TAC for review. The goal is to formulate, as a community, a complimentary set of PI led Science Use Cases (team or individual efforts) that together, as the Critical Science Plan, capture the most compelling critical science.

3. Conversion and translation of Science Use Cases into DKIST Observing Proposals
4. Observations at the DKIST following approval by the Time Allocation Committee (TAC)
5. Analysis and publication, to include:
   a. analysis of science data
   b. feedback to project (for analysis package development)
   c. PI led team publication of scientific results, as appropriate, in special volumes highlighting critical DKIST first-light science results

http://dkist.nso.edu/CSP

Critical Science Plan Structure:

Research Areas

Research Topics

Science Use Case

↓

Observing Proposal

↑

Bottom-up approach:

CSP is built on community led Science Use Cases *some of which* will be executed as Observing Proposals

DKIST Critical Science Plan (CSP)

Important Points:

1. This process will likely be iterative – CSP structure (that you see on the website) is intended as a helpful but non-rigid framework and the science will evolve.
2. The CSP process is not exclusive (all welcome) nor unique (direct submission of observing proposals to the NSO DKIST Time Allocation Committee (TAC) under a standard submission and review process will also be possible). The CSP (and this workshop) advantage is informational.
3. Observing proposals developed as a result of participation in the DKIST Critical Science Plan effort (including this workshop) will be reviewed by the NSO DKIST TAC along with proposals submitted outside of the CSP structure.
4. There is *no* automatic conversion of Science Use Cases to Observing Proposals – success is dependent on continued engagement beyond this workshop proper and beyond the completed Science Use Case.
5. The development of the CSP in advance of the start of operations helps the project beyond science definition – it helps in the development of essential operations and data management tools

Science Use Case → Observing Proposal → TAC review → Observations

DKIST Science Working Group

DKIST Science Working Group (DKIST SWG)

1	Bello-Gonzales	Nazaret	KIS	Germany	Member
2	Cao	Wenda	NJIT	US	Member
3	Cauzzi	Gianna	AO	Italy	Member
4	Cranmer	Steve	U. Colorado	US	Member
5	da Costa	Fatima Rubio	Stanford	US	Member
6	DeLuca	Ed	Harvard	US	Member
7	dePontieu	Bart	Lockheed	US	Member
8	Fletcher	Lyndsay	U. Glasgow	UK	Member
9	Gibson	Sarah	HAO	US	Member
10	Jeffries	Stuart	Georgia St	US	Member
11	Judge	Phil	HAO	US	Member
12	Katsukawa	Yukio	NAOJ	Japan	Member
13	Landi	Enrico	Michigan	US	Member
14	Petrie	Gordon	NSO	US	Member
15	Qiu	Jiong	MSU	US	Member
16	Rast	Mark	U. Colorado	US	Member
17	Rempel	Mattias	HAO	US	Member
18	Rubio	Luis Bellot	IAA	Spain	Member
19	Scullion	Eamon	TCD	Ireland	Member
20	Sun	Xudong	IfA	US	Member
21	Welsch	Brian	Wisconsin	US	Member
22	Goode	Phil	NJIT	US	Co-I
23	Knoelker	Michael	HAO	US	Co-I
24	Rosner	Robert	U. Chicago	US	Co-I
25	Kuhn	Jeff	IFA	US	Co-I & Instrument PI
26	Rimmele	Thomas	NSO	US	Ex-Officio
27	Casini	Roberto	HAO	US	Instrument PI
28	Lin	Haosheng	IFA	US	Instrument PI
29	Schmidt	Wolfgang	KIS	Germany	Instrument PI
30	Woeger	Friedrich	NSO	US	Instrument PI

- SWG will try to articulate the community vision of essential DKIST science through the Critical Science Plan
- The SWG will identify Science Use Case overlap and suggest team consolidation
- The SWG will aim to minimize, NOT adjudicate, conflicts
- The SWG will assess whether the science proposed in the Science Use Cases requires DKIST capabilities
- DKIST Time Allocation Committee is final arbitrator, and will determine the order which the Observing Proposals are executed

DKIST Instruments: Coronal Capabilities

DKIST Coronal Capabilities: Cryo-NIRSP

Cryo-NIRSP: Cryogenic Coronal Spectropolarimetry

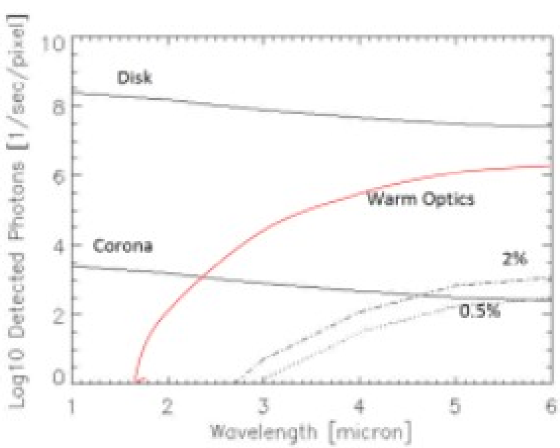
Cryo-NIRSP

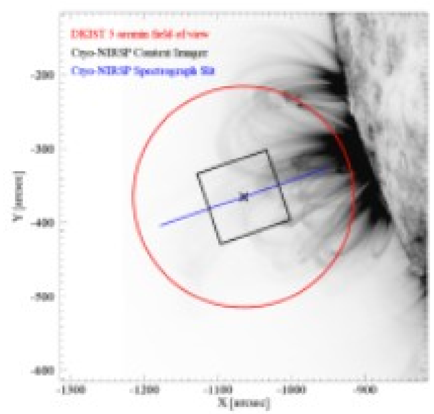
Fe XIII	1074.7nm
Fe XIII	1079.7nm
He I	1083 nm
Si X	1430nm
Si IX	3935 nm
CO	4651nm

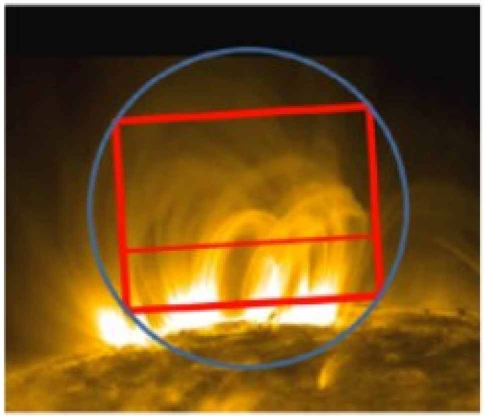
Cryo Context

Fe XIII	1074.7nm
He I	1083nm
J Band	1250nm
Si IX	1430nm

Pioneering low background, high-dynamic-range coronal spectropolarimetry out to 5 microns. Most extensive coverage of infrared coronal lines with high efficiency.







Example 1:
Si IX 3.9 um slit-scanned spectropolarimetry
3' x 4' region, 1'' samples, 5G sensitivity near limb, 15G at 1.5 solar radii, 3 hr scan

Different species (e.g. Fe XIII pair) observable in sequence with ~70 second spectrograph reconfiguration time (calibration overhead TBD). Context imager field always centered on slit.

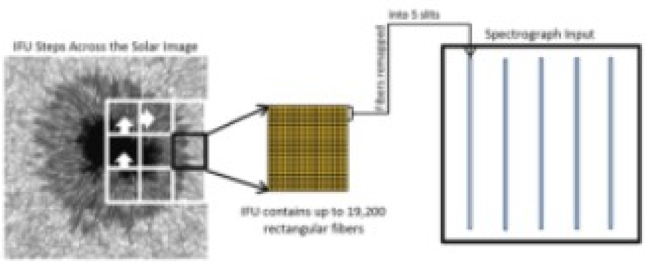
(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities: DL-NIRSP

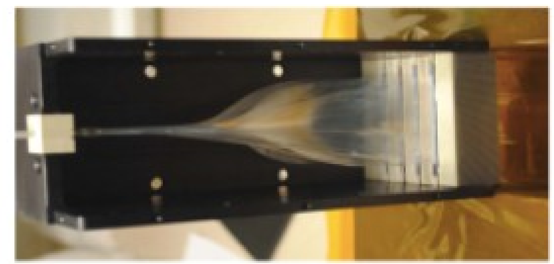
DL-NIRSP: Multi-band Integral Field Coronal Spectropolarimetry

DL-NIRSP	
Fe XI	789nm
Ca II	854.2nm
Fe XIII	1074.7nm
He I	1083nm
Si X	1430nm
Fe I	1565nm

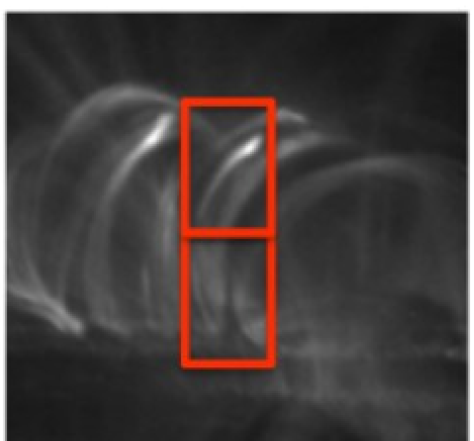
Fiber-optic based integral field spectropolarimetry with up to three simultaneous channels. Instantaneous spectrograph coverage over a 2D field.



One tile at a time, DL-NIRSP builds spectropolarimetric full data cubes: [X ; Y ; λ ; S [=I,Q,U,V] ; t]



More filters recently added:
Fe XIV 530.3 nm
He D3 587.6 nm
Fe I 630.2 nm
Fe XIII 1079.8 nm



- DL-NIRSP wide-field mode consists of 60 x 40 IFU with 0.464'' samples. (FOV: 18.6'' x 27.8'')
- 2D scanning for up to 2' x 2' FOV for single telescope pointing.
- Example: 1 x 2 scan pattern, total FOV 18.6'' x 55.7'', 16 sec integration (SNR ~50), 33 sec cadence.
- Resolve MHD wave propagation/dynamics and do temporal coadding for magnetic field inference.

(Slide borrowed from Tom Schad)

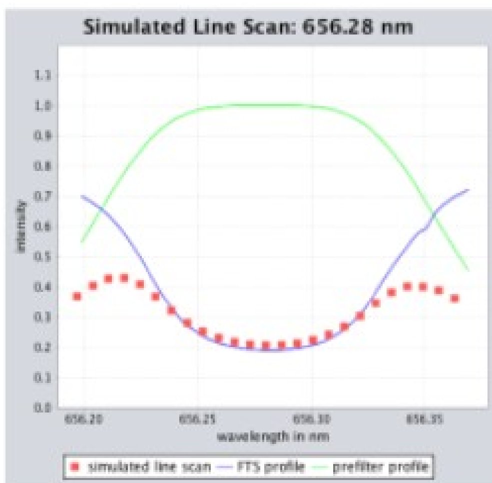
DKIST Coronal Capabilities: VTF

VTF: Cool Coronal Dynamics

VTF	
Na D	589.6nm
Fe I	630.25nm
H-alpha	656.3nm
Ca II	854.2nm

- Thermal coverage of VTF does not include hot coronal plasma.
- High-cadence imaging spectro(polarimetry) of cool lines (H-alpha and Ca II)
- Prominences; coronal rain; post-flare cooled loops.

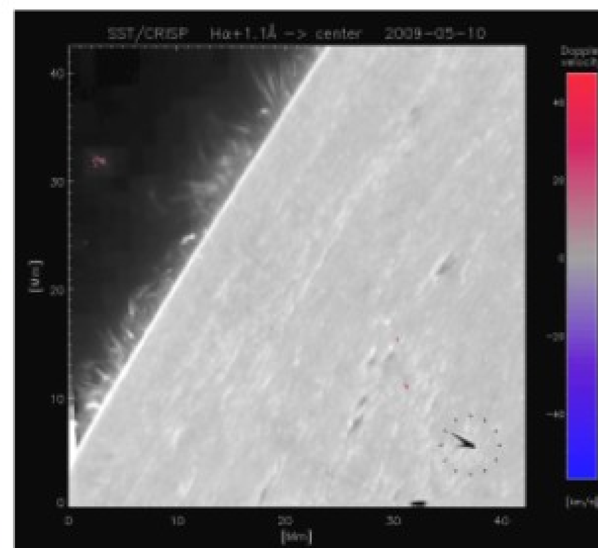
VTF FOV: 60'' x 60'' (no scanning)



Line Counter	Line 1		
Line	HI_656.28		
Scan Mode	blue-red		
Binning	1x1		
ROI	4096x4096		
Central Wavelength (nm)	656.28		
Exposure Time	25.0		
Steps: Left-Right-Sum	-12	12	25
Spectral Step (pm)	6.91	x2	
Accumulations	4		
SNR	227.0		
Scan Position (nm)	0		
Repeats	0		
Cycle Time (sec)	4.25		

Example: H-alpha spectroscopy (+/- 34 km/sec) in 4.25 sec

Coronal rain observed by SST/CRISP 60'' x 60'' FOV (Antolin et al. 2012)



(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities: ViSP

ViSP in the Corona

ViSP

Access to entire spectral range between 380-900 nm

- VISP science cases emphasize photospheric/chromospheric/prominence science.
- Attractive coronal science includes diversity of visible line diagnostics.
- Increase of scattered light in visible; Zeeman sensitivity reduced.
- IPC does not give coronal estimates (but some capabilities can be assessed).

Example 1: Simultaneous scan of three coronal lines 0.214'' slit width (widest), 1'' scan step, 5 sec total integration 100'' scan width → 9 minutes to map				FOV along slit	Telescope + ViSP transmission	Spectral Resolution
Fe XIV	Log T ~ 6.3	530.3 nm	'Green' line	75''	1.23%	90000
Ca XV	Log T ~ 6.65	569.4 nm	'Yellow' line	60''	1.85%	89000
Fe X	Log T ~ 6.05	637.5 nm	'Red' line	50''	0.73%	79000

Example 3:
2MK FIP Effect

S XII 761.2 nm
Fe XV 706.2 nm

Example 2: Ca XV density line ratio sit and stare 0.214'' slit width (widest), a few seconds of int per step				FOV along slit	Telescope + ViSP transmission	Spectral Resolution
Ca XV	Log T ~ 6.65	569.6		75''	2.26%	78000
Ca XV	Log T ~ 6.65	544.6		60''	2.34%	75000

(Slide borrowed from Tom Schad)

DKIST Coronal Capabilities: VBI

VBI in the Corona: Direct Multi-Thermal Coronal Imaging

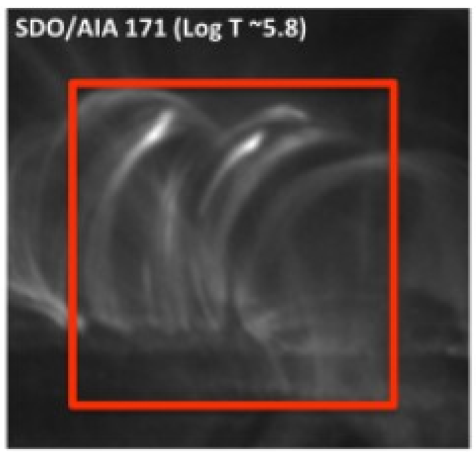
VBI Blue

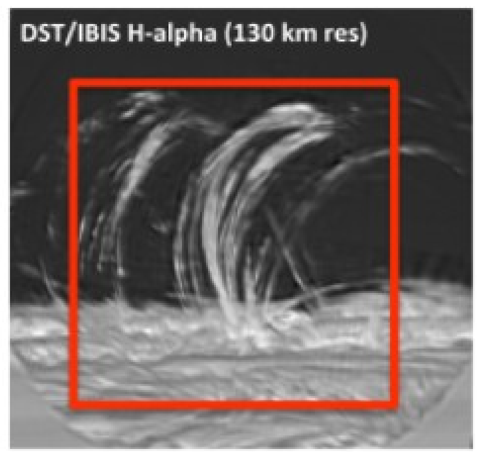
Ca II K	393.327nm
G-band	430.52nm
Continuum	450.287nm
H-beta	486.1nm

VBI Red

H-alpha	656.282nm
Continuum	668.423nm
Ti O	705.839nm
Fe XI	789.186nm

<u>**Key targets**</u>: Bright post flare loops and other cooling loops





VBI-red 69'' x 69'' FOV
(Field sampling to 2' x 2')
0.017'' spatial sampling

VBI-red coronal filter
Fe XI 789.2 nm (Log T ~ 6.13)
1 to a few second cadence
(no off-band subtraction)

Direct imaging of green line from Sac Peak (20 cm Coronal One Shot) Airapetian and Smartt, 1995, ApJ

(Slide borrowed from Tom Schad)

The SolO-PSP-DKIST workshop

The Workshop

- **The road to the workshop:**
  - Splinter at Solar Orbiter Workshop #7 (Granada, Spain, 3 April 2017)
  - Splinter at PSP SWG Meeting (JHU/APL, Laurel, MD, USA, 6 October 2017)
- **The workshop**
  - JHU/APL (Laurel, MD), 13-15 March 2018
  - Participants, presentations, support documents:

    https://eclipse2017.nso.edu/science/dkist/dkist-critical-science-plan/workshop-4/
- **17 participants (2 remotely)**

  Note: G. Cauzzi also acting as CSP Workshops Coordinator for NSO. NSO Support scientist: A. Tritschler
- **Also participating:**
  - David Boboltz (NSF, Program Director)
  - Slava Lukin (NSF, Program Director)
  - Ilia Roussev (NSF, Program Director)

Participants

- Vincenzo Andretta
- Luis Bellot Rubio
- Gianna Cauzzi *(also NSO CSP Workshops Coordinator)*
- Sarah Gibson
- Shadia Habbal
- Louise Harra
- Yuan-Kuen Ko
- Jon Linker
- Sarah Matthews
- Susanna Parenti
- Nour E. Raouafi
- Daniele Spadaro
- Ignacio Ugarte-Urra
- Angelos Vourlidas
- Harry Warren
- Andreas Lagg *(remotely)*
- Eamon Scullion *(remotely)*
- Anik De Groof (ESA)
- Valentin Martinez Pillet (NSO)
- David Boboltz (NSF)
- Slava Lukin (NSF)
- Ilia Roussev (NSF)

NSO Supporting Scientist:

- Alexandra Tritschler

Current List of Science Use Cases

- **Polar fields/dynamo:**
  - UC-161 (L. Bellot Rubio): Stereoscopy of polar magnetic field
  - UC-160 (J. Linker): What is the Magnetic Flux in Coronal Holes?
  - UC-152 (A. Lagg): Helicity mapping for dynamo studies (also in coordination with solar Orbiter high-latitude phase)
  - UC-151 (A. Lagg): Polar magnetic fields from two vantage points: joint observations with Solar Orbiter
- **Stereoscopy (miscellanea)**
  - UC-158 (V. Martinez Pillet): Understanding the Line-of-Sight integration in Coronal observations
  - UC-159 (H. Warren): Stereoscopic Observations of Loops and Magnetic Fields
  - UC-154 (S. Matthews): Searching for flare current sheet instabilities with DKIST and Solar Orbiter
  - UC-153 (A. Lagg): Stereoscopic magnetic field measurements: joint observations with Solar Orbiter / PHI
- **CMEs/Prominences**
  - UC-89 (D. Spadaro): Tracking the evolution of Corona Mass Ejections plasma
  - UC-155 (S. Gibson): Coronal prominence cavity systems - with DKIST-Solar Orbiter joint observations
- **Solar Wind/properties and dynamics**
  - UC-157 (Y.-K. Ko): Waves and turbulences in the nascent solar wind with Solar Orbiter and Parker Solar Probe
  - UC-156 (N.E. Raouafi): Plasma Dynamics and Inner Structure of Coronal Plumes
  - UC-162 (L. Harra): DKIST and Solar Orbiter observations for understanding upflowing plasma on the Sun: limb observations for DKIST, quadrature for SO.
  - UC-61 (L. Harra): DKIST and Solar Orbiter observations for understanding the creation of upflowing plasma on the Sun - on disk observations.
  - UC-88 (D. Spadaro): Properties of the solar wind source regions investigated by DKIST and Solar Orbiter
- **Solar wind/Abundances**
  - UC-64 (S. Parenti): FIP fractionation as tracer of solar wind source regions from joint DKIST and Solar Orbiter observations.
  - UC-60 (V. Andretta): Coronal helium abundance from joint DKIST and Solar Orbiter observations

From SUCs to observations

A possible scheme of interaction with Solar Orbiter and PSP

- Consolidation of Solar Orbiter relevant Science Use Cases, making sure that all the SUCs contain the necessary information (work in progress)
- Mapping DKIST CSP UCs with Solar Orbiter SAP and PSP science objectives (TBW).
- Workshop on operations planning, including in-situ PIs (spring 2019?).
- The team (PI of Solar Orbiter/PSP SUCs?) submits a proposal to the DKIST TAC for a “target of opportunity” observing mode.

  For Solar Orbiter SUCs, to be done after launch date is fixed and the Solar Orbiter Windows relevant to the SUCs are known. The proposal will request the necessary observing time to develop the SUCs.

- If an unforeseen window of opportunity with Solar Orbiter appears, it is still possible to apply for NSO Director’s discretionary time.

  This, of course, may be challenging depending on what will be requested and what DKIST is doing at this time.